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An Account *of the* Recent Researches *into the* History *of the* Bacteria, *made by, and under the direction of,* Prof. Cohn.[1] By F. Jeffrey Bell, Exhibitioner of Magdalen College, Oxford. (With Plate XX.)

In the April number of the 13th volume of this Journal (1873), an account was given of the first series of observations on Bacteria which Professor Cohn had published in his valuable 'Beiträge zur Biologie der Pflanzen' (Heft 2); in the 3rd Heft, published last year, the subject is continued by Cohn, in addition to whom Eidam, working in his laboratory, gives an account of certain experiments made on these interesting organisms. Since the publication of the previous paper the discussion concerning spontaneous generation has changed in aspect; Dr. Burdon Sanderson has given an account of several Bacterioid forms, in his Reports to the Medical Officer of the Privy Council, and Professor Ray Lankester has called the attention of readers of this Journal to the subject by his very interesting account of "a peach-coloured Bacterium." To the wide interest exhibited in these forms Cohn briefly refers, but mentions at greater length the work of Billroth, published by George Reimer, of Berlin, in 1874.[2] I shall try to give in the following pages an account of these two new papers, but must refer all who are really interested in the matter from whatever point of view, philosophical, botanical, or pathological, to the originals them-

[1] 'Beiträge zur Biologie der Pflanzen,' 3es Heft, 1875.
[2] 'Untersuchungen über die Vegetationsform von Coccobacteria septica,' &c.

selves, assuring them that diffuseness will not be found to be a characteristic of this memoir. Notwithstanding Billroth's work, Cohn holds firmly to his original position, that the Bacteria should be arranged in genera and species, and not united into a single polymorphous species—*Coccobacteria septica* (Billroth), as has happened to all the forms described by him, with the exception of *Spirillum and Spirochæte,* under the hands of Billroth. Readers of this Journal will remember that Mr. Lankester speaks of *B. rubescens* as a Protean species. Against such a view Cohn argues that the changes of form are not fully proved, nor does he think that such a way of looking at these organisms will be as conducive to progress in our knowledge as his more objective method. With so much by way of introduction we will proceed to the consideration of the various forms which Cohn examines, one by one; it will I think conduce to clearness, if we follow his example.

1. The first examined is the *Ascococcus,* studied by Billroth. In the careful observation of the Bacteria-films found in water, containing muscle in a state of decomposition, or on hydrocele, and such like fluids, Billroth noticed a certain grey or greenish-grey organism, rounded in contour, of a knobbed or cylindrical form; the scum which they produce may attain 0·5 mm. in thickness, and forms, on account of its circumscribed position in jars, and such vessels, distinct folds; it finally sinks to the bottom of the vessel as a flocculent precipitate. These folds are caused by "a peculiar vegetative form of the coccos," which Billroth calls *palmelloid.* If embedded in "*coccoglia*" Ascococcus forms spheres or cylinders of Micrococcus, united into colonies, and held together by a remarkably fine glia; around such a scum no membrane has ever been observed, notwithstanding its definite outline; but the presence of it is to be considered as probable; and it is, indeed, remarkably thick in fluids containing beef, with sugar.

The history of this form is, according to Billroth, of the following character: several large cells form, by transverse division, long, cylindrical, and spiral tubes, in which appear chains of cocci by longitudinal division, and branching; these repeated branchings produce very small (micro) cocci; when this has gone on for a certain time, micrococci escape by the bursting of one side; and the envelope which is left is seen to have a double contour, and is easily recognisable by its greenish-brown colour. One remarkable form of this genus, which Billroth calls *A. parvus,* has been found by him in water containing flesh; it is a pale finely-

granulated ball, not unlike an unnucleated lymph-corpuscle, which swims about by means of cilia, like the contractile Myxomonads, and soon, developing long processes, comes to resemble a Myxamœba; this form, however, Billroth regards as the encysted spore of a Myxomycetes (perhaps Æthalium septicum), while the micrococci within it have been simply eaten; if this be Ascoccocus—and Cohn thinks that it is not a Bacterian form—it is clear that Billroth has described two things under one name; the other form Cohn has, however, found, and describes as *Ascococcus Billrothii.*

2. This form he observed, not in putrescent fluids as did Billroth, but by the examination of air collected by a new process which he describes in this paper, and which is of sufficient importance to detain us for a short time. Being busied, he says, in the beginning of 1874, with the important question, as to whether germs of Bacteria capable of development under normal conditions are to be found in the air, he invented—after rejecting the processes of Pasteur and Pouchet—a method by which the Bacteria-germs, if present, are passed through a solution in which they are able to develope. Air was passed by means of an aspirator through a series of wash-bottles, which were filled with twenty grammes of his "normal fluid," the composition of which he gave in his previous essay. Two large glass bottles, each of which held ten litres, and which were made air-tight by bungs served as the aspirator; through each bung passed two glass tubes, bent at right angles, one passing to the bottom of the bottle, and the other reaching just below the bung; one bottle then being filled with water, and placed at a higher level than the other, and the tubes united by caoutchouc piping, the desired current was produced. The upper bottle was now united by caoutchouc piping to the series of wash-bottles, and the air passed in, in bubbles. When the lower bottle becomes full, it changes place with the upper; and this change, with the consequent alteration of the piping, is the only trouble to which the experimenter is put by this method; while the volume of air which enters is easily known, as ten litres are washed in each experiment. The importance of this arrangement is, as Cohn points out, that the germs develope, and the various species can be named macroscopically, while with the ordinary methods of examination of air it is impossible to do this, as the spores or germs are only seen, as such, and that by the aid of the microscope.

As precautionary measures, all the glass vessels used must be boiled for a long time in the water bath; corks are to be avoided, as they shelter spores in their cracks, and glass

stoppers or gutta percha used in their place; and, lastly, the connection of the vessels which contain the nutrient solution must be so arranged, that no entrance of spores is possible after they have been boiled.

The passage of the air bubbles was regulated by a clip placed on the tubing, so that the ten litres of air took one to two hours in passing over. Notwithstanding this precaution an uncertain quantity of spores passed, apparently carried by the air bubbles, through the washbottles. After a certain quantity of air had been "sucked through," a precipitate or a troubling of the contained water was observed in these washbottles; white clouds of mycelium were, in all cases, observed on their walls and bottoms, which grew rapidly, and were easily seen by the naked eye; while on the surface of the nutrient fluid the mycelia fructified, and often allowed Cohn to see their hyphæ bearing the conidia. To hasten development he was in the habit of placing the washbottles, after a time, in his warm chamber (described Heft II, p. 196) at a temperature of 30° C. In one bottle he placed Pasteur's solution (with sugar), and in the other the normal Bacteria solution (without sugar). He always found *Aspergillus* and *Penicillium;* which he was able to distinguish from each other, by the loose character of the mycelium of the former. *Mucor* was found only once. On the natural assumption that each growth developed from one spore, Cohn finds that one such, capable of development, was obtained in every ten litres of air; and concludes from this that a man takes in 1000 such every day, of which, of course, the greater number are again passed out in expiration, or are in some way prevented from developing.

The cloudy appearance of the fluids was largely due to circular Torula cells, united in couples; the oval smaller form was rare; in the precipitate were found smut and other fungus-spores. "*As a rule no Bacteria were developed in the fluids of the washbottles;*" because, as Cohn thinks, they were with difficulty held back by the water, and rather passed over in the air bubbles without being wetted, as is the case with the spores of Lycopodium (Heft II, p. 189); he supposes, in effect, that they can only develope when thoroughly wetted through,—a condition which does not easily obtain, unless they fall on a dirty surface, and are wetted there; as Cohn points out, these observations agree with those of Burdon Sanderson, although he is convinced that, when Bacteria did appear in the aspirator-bottles, they were really brought in by the bubbles of air, and washed out from them,

and that their presence was not to be ascribed to any chance contact of surfaces.

3. Imbedded in a fluid which also contained *Micrococcus crepusculum*, Cohn found aggregations of varying size more or less circular in form, which, with their surrounding membrane, closely resembled frog's ova; one or more new aggregations were found in one membrane, the smaller circular, the larger irregularly elliptical; the latter formed a "cartilaginous" corpuscle, which was with great difficulty broken by pressure, not dissolved by ammonia, or coloured by iodine; but within them he found an aggregation of much smaller bodies of circular form, capable of being stained yellow with iodine, which were united together by a remarkably firm intercellular substance, and surrounded by a very thick cartilaginous envelope. These fresh characters are those of the genus *Ascococcus*. The cell-families thus formed break up into "nests" of irregular form, which are further divided into lobes, which are again subdivided into lobules, giving, in this way, to the whole the appearance of a bunch of grapes. Their development takes place in the following manner: small families of Micrococci are pushed towards the periphery of the surrounding gelatinous membrane, increase enormously, and thus get closely applied to one another; the gelatinous membrane grows at the same time; branches then appear, and the whole takes on a knobbed or iregularly bunch-like appearance; the larger lobes are, by further division, broken up into smaller ones, the membrane still embracing the whole family; but this separates the lobes when they grow too large, and produces forms of the appearance represented in figs. 4 and 5; and thus at last there are produced families of *Ascococci*, which, at first small and circular, become gradually larger, till they reach the stage represented in fig. 3.[1]

The chemical activity of this form is very remarkable; thus, it gives rise to a peculiar milky or cheesy odour, arising, as Cohn thinks, from the production of lactic acid, and lactic ether from ammonium tartate; and, further, the originally acid reaction of the nutrient solution is changed into one intensely alkaline, due apparently to the presence of free ammonia, which is very easily recognisable.

Although Cohn is not quite certain as to whether this form is really the same as that which Billroth has already called by this name, he thinks it probable that it is so; in

[1] These numbers refer to Cohn's figures. Fig. 1 of our plate gives a good idea of the general appearance.

any case he thinks his form one of generic value, and adds the following diagnosis of its characters :

Ascococcus, Billroth, char. emend. Cellulæ achromaticæ minimæ globosæ densissime consociatæ in familias tuberculosas globosas vel ovales irregulariter lobatas, lobis in lobulos minores sectis, capsula globosa vel ovali gelatinosa cartilaginea crassissima circumdatas, in membranam mollem facile secedentem floccosam aggregatas.

A. Billrothii, *n. sp., familiæ tuberculosæ* 20—160 *mikrom. capsula ad* 15 *mikrom. crassæ. In solutione ammonii tartarici acidi aëre lavata sponte ortum, membranam odore lactico vel butyrico præditam formantem observavi Mart.* 1874. *Haud scio utrum eandem an affinem speciem ill. Billroth in aqua carnis fœtida detexerit.*

4. Although, at first sight, the developmental history of *Ascococcus* is so remarkably strange, it appears to fill up a blank in the relations of the genus *Micrococcus* to the family of the *Chroococcaceæ;* for, in this family, there are forms either spherical or cylindrical, solitary or loosely connected, or forming distinctly limited colonies united by membranous intercellular substance; the genera *Glœothece, Microcystis, Polycoccus,* and *Anacystis,* for example, make solid balls formed of very small round cells, united by intercellular substance, and surrounded by an envelope of varying thickness; in *Polycystis* there are found several *Microcystis* colonies, with a common investment; while in *Cœlosphærium* the cells are found only at the periphery of the membrane, and so form a hollow sphere. Now, while *Ascococcus* is separable from *Microcystis, Anacystis,* and *Polycystis,* by the absence of colour in its cells, the developmental history of *Cœlosphærium,* as related by Naegeli, Unger, and specially Leitgeb, is strikingly analogous to that of *Ascococcus;*[1] *C. Naegelianum,* Unger, is a free-swimming form found on the surface of a pond at Graz, the cell-families of which form hollow spheres; these may unite to form 2—6 spheres with flattened edges; with furrows, more or less deep, and more numerous as the families are larger, on the surface; cell gradations between families with altogether indistinct furrows, and united families are to be found; these latter may be broken up by pressure on the cover glass, but they also separate of themselves, and thus increase in number; in addition to this mode of propagation, which is the more

[1] Cohn gives the following references: *Unger,* 'Denkschriften der K. Akad. der Wiss.' Band. vii. *Leitgeb,* Mittheil. der naturwiss. Vereins für Steiermark. Bd. ii, Heft 1, 1869. Tab. II.

common, single cells may leave the colony, and by repeated divisions form a new family.

The genus *Clathrocystis,* the cell-families of which are at first solid, and, later on, form hollow spheres of a beautiful pale green colour, and from 0,024—0.5 mm. diameter, presents a still more remarkable mode of division; which was first described by Henfrey,[1] in 1856, who saw numerous gonidia appear on the surface, in a single layer, imbedded in a colourless matrix; gradually the hollow sphere takes on the appearance of an irregular net, by the enlargement of fissures, arising at the periphery; the whole breaks up into fragments, which grow again into hollow spheres.

5, 6. Cohn now goes on to describe a new species of this genus, to which he has given the name *Clathrocystis roseo-persicina,* which he has found on leaves and like matter decaying at the bottom of glass vessels, as spots of a bright peach-bloom-red colour; under the microscope they appear as loosely aggregated cells, rounded or oval, which are either homogeneous or appear to be hollow, in which case the cavity is filled with one or more dark granules. Care must be taken not to confound with them other microscopic organisms, which have no real genetic connection with them, although of a similar colour. The first supply which led to the investigation of this form was received from Dr. Kirchner, who assisted Cohn in his labours; his specimens were found in a pond near Breslau, either on the surface of the water or mixed up with *Vaucheria, Spirogyra,* &c. Material was also received from Dr. Warming, of Copenhagen, and Mr. Ray Lankester, of Oxford. Much of the interest, indeed, taken in this plant is due to the investigations of Professor Lankester, published in this Journal, in October 1873;[2] this paper will be known to all our readers. The specimens found growing on other plants were of irregular form, but with a sharply marked contour, and consisted of cells united by a common gelatinous membrane; the free-swimming forms were hollow spheres, of a diameter not exceeding 0·6 mm. The contents were clear and fluid; and often the spheres exhibited cracks, with similar spheres and hemispheres arising from them; the single cells were very small, only 2·5 microm.,[3] at times, in diameter, of circular, oval, or—owing to pressure—angular shape. The shades of colour, exhibited by their contents,

[1] 'Quart. Journ. Microsc. Science,' 1856.

[2] 'Quart. Journ. Mic. Sci.,' vol. xiii., N. S., p. 408. Pl. xxii, xxiii, and again vol. xvi, p. 27.

[3] 2·5 Micromillimeters = 0.0025 mm.

always gave the Bacterio-purpurin absorption bands (Lankester), and exhibited the same chemical characters as that colouring matter, which is quite different to that of *Monas* (*Micrococcus*) *prodigiosa*. The cell-membrane, which resembles that of Glœocapsa, is generally very distinct, on account of this coloration; within are to be found very remarkable, dark granules; on account of their intercellular substance, which ordinarily separates the cells from one another by about their own diameter, Cohn would place this alga among the *Chroococcaceæ*; in addition to this, there is a general membrane for the cell-family, which is, however, observed with difficulty, unless some such pigment as carmine or gamboge be added to the water. The observation of their development is not altogether easy; at first the cell-families have not a circular but a vesicular or sack-like form; often, by the excessive development of cells in a certain direction, the whole takes on a bell-shaped form; these gradually become spherical, and further increase by the appearance of tertiary protuberances. If this *Clathrocystis* suffers from a want of water, daughter-cells are not formed, and the cell-families come to resemble Hydrodictyon by the appearance of large spaces in their midst; breaking up into smaller portions, they sink to the bottom of the vessel, and find a resting-place, on the decaying animal and vegetable matter which may happen to be there; from these, in time, spring up well-formed circular, and even net-like families of cells (fig. 10).

A remarkable mode of reproduction still remains: Cohn discovered young cell-families containing a definite (16—64) number of cells, united into a regular sphere, in such a way that they were closely pressed to one another, and seemed to fill the sphere; they differed from the rosy-peach-coloured families by an intensely purple-red coloration; but still more, by exhibiting spontaneous movement, turning round and round like *Volvox* or *Pandorina*; of its cause and of the length of its duration nothing can be said, but no such movement has ever yet been observed in any of the allied *Chroococcaceæ*.

7. *Monas vinosa* (fig. 13), Ehr. Next in order our author deals with the actively mobile, red corpuscles, which go under this name, and which he found in the same vessel with the peach-coloured *Clathrocystis*; of regularly spherical or oval form, often found in couples, their greatest diameter was 2·5 mikrom.; nothing could be seen of them save a pale red substance, in which were embedded darker granules; even cilia could not be seen. Their swarming movement was quite distinct from the ordinary trembling molecular movement, and it was

due to it that they were enabled to collect themselves in groups on that side of the vessel which was turned to the light. Cohn thinks this form to be identical with that described by Ehrenberg in his 'Infusions-thierchen,' p. 11, in 1838. Charles Morren observed it, and gave an account of it to the Academy at Brussels in 1841, as forming the wine-red palmelloid crusts, which often extend to several inches in breadth, over water in which *Pteris aquilina* is decaying.[1] Perty's form *Chromatium* (*Monas*) *violescens*, Cohn thinks is probably the same as that described by himself as *M. vinosa.*

8. *Monas Okenii* (fig. 12). Specimens of this form, which were also made known to science by Ehrenberg, were obtained through Dr. Hirsch, of Kahla in Thuringia, from a very rich pond in that place, the water of which was coloured red; the cause of this was the presence of a short cylindrical organism, ordinarily twice or three times as long as it was broad, with a diameter of ·005 mm., and a long axis varying from ·0075 to ·015 mm., according to the state of division in which it was found, with the ends rounded and generally slightly bent. It was found in enormous quantities, turning slowly on its axis; with this period of activity there alternated one of rest; they were mostly to be found on the side of the glass which was turned to the light; at first no organ of movement was seen, but the addition of iodine solution brought out a very long flagellum of more than twice the length of the body, behind which it was carried straight, or bent spirally. Just as in his *Clathrocystis*, Cohn found a varying number of dark granules in the interior of the organism; if one be dried, and alcohol added, the granules become coloured, and leave the protoplasm colourless, while one or two vacuoles appear in the limiting membrane. Acetic acid colours them a bright red; ammonia dissolves them, and gives a brownish-red colour to the pigment. These red corpuscles are the chief nourishment of the various kinds of animals, found in the water which they inhabit; curiously enough, their coloration in the Rotifera gives us some idea of the characters of the secretions of these animals; in the true stomach the corpuscles were of a bright red, due, as Cohn thinks, to the acid reaction of the gastric juice; while in the other portions of the intestine they were of a dark or brown-red colour, which was due to its neutral or alkaline reaction. They appear to propagate by fission.

Cohn now describes two new species, the leading characters of which must be rapidly enumerated:

[1] Mém. de l'Acad. de Bruxelles, 1841, p. 70.
[2] Perty, Kleinste Lebensformen, 1852, p. 174.

9. *Rhabdomonas rosea*, n. sp. This form, which also came from Kahla, had a spindle-shaped appearance, with pale rosy-red corpuscles within, of ·0038—·005 mm, and a length ·02—·03 mm.; the cells were single and the corpuscles were dark, and highly refractive, in addition to which vacuoles were observed at the middle and ends; their movement was a trembling backwards and forwards, with a continual turning around their long axis; he has no doubt of the existence of a flagellum, though he only once saw it with distinctness.

10. *Monas Warmingii*, n. sp., was obtained from Dr. Warming, of Copenhagen, who found it in pools of brackish water, where marine plants were decaying, in the company of nearly all the forms—except *Ascococcus*—which have been described above; it resembled, save that it was broader, *Monas Okenii*; the body was clear, and the contained protoplasm firm and of a pale red, filled with dark red granules, *only at the rounded extremities*; length ·015—·02 mm., breadth ·008 mm.; their movement was irregular (taumelnd), but much more active than that of *M. Okenii*; posteriorly, there projected a flagellum; when division of the cells is about to occur, the middle, which was before devoid of granules, becomes filled with them, so that when division is accomplished the two new cells have the characteristic terminal groups of granules, at once; this form also differs from *M. vinosa* of Ehrenberg in its larger size.

11. *Ophidomonas sanguinea*, Ehr., a form of varying size and breadth, which Cohn found in Dr. Warming's water, is thought by him, after a long consideration, to be the same as that discovered by Ehrenberg in 1836. Although, indeed, since Cohn has himself shown, that *Spirillum volutans* has a fine flagellum at each end,[1] there is no difference between *Spirillum* and *Ophidomonas*; unless the smaller species (*S. termo*, *S. undula*) be shown not to possess flagella, when the generic term *Spirillum* would be justly theirs.

12. But a more important question is the relation of the Bacteria to the Monads; on the one hand, it may be said that the Monads are Bacteria. The Monad form here called *Clathrocystis roseo-persicina* was considered by Prof. Ray Lankester as a "peach-coloured Bacterium;" and Ehrenberg supposes that all the Bacteria possess cilia, (Frau Lüders, as stated in the account of Cohn's earlier paper, has asserted the occurrence of one flagellum in B. termo[2]); and if this be the

[1] 'Quart. Journ. Mic. Sci.,' April, 1873.
[2] *loc. cit.*, p. 158.

case, the Monads here described differ from them merely in their size. But on the other hand, certain Bacteria have very evident relationship with the *Oscillariæ* and *Spirulinæ*, which certainly do not move by the aid of flagella.

13. The highly refractive granules, already noticed in so many forms, and which are to be found even in the uncoloured Bacteria, are best known and most interesting in the genus *Beggiatoa*, specimens of which are to be found in every sulphur spring, as well as foul ditches, or other pieces of water containing a large quantity of organic matter.

14. This last Alga seems, indeed, to be the cause of the production of sulphuretted hydrogen, in the water in which it is found.

15. The two following sections on the separation of sulphur are of the very highest interest. On the fertile water received from Dr. Warming, Cohn observed a chalky scum, which was seen, by the aid of the microscope, to consist of small highly refracting granules, which did not effervesce on the addition of dilute acids; thinking, fairly enough, that this was due to the formation of sulphates, he applied other tests, which convinced him that he had to do with pure sulphur.

The formation of sulphur evidently depends on (1) the presence of a large quantity of sulphates in the water; and (2) on the absence of iron salts, which would cause the formation of ferrous sulphide. Now arises the question, is the formation of free sulphuretted hydrogen due to decaying or to living organisms? Although unable fully to resolve the question Cohn thinks the living organisms are the chief agents in the matter; for, in the first place, three species of *Beggiatoa*, one of which (*B. alba*) is found in hot sulphur springs, have been observed in such water, and the red-coloured organisms, already spoken of, seem to be not innocent; for they, like *Beggiatoa*, appear to increase under such conditions of impurity as would be fatal to all other organisms.

And, further, Morren, Fontan and Joly, and Menighini, have observed red or peach-coloured forms in sulphur springs. If this supposition, that such organisms can sustain life, in water full of free sulphuretted hydrogen, and consequently greatly wanting in free oxygen, be correct, we have to do with a most remarkable phenomenon; from which it may be very justly concluded, without fear of appearing hasty in

[1] Meyer: 'Journal für Prakt. Chemie,' xci, 1, Hedwigia, 1865, No. 6, p. 81, &c.

drawing conclusions, that one form of activity in the circle of vital processes which certain organisms exhibit, is the production of free sulphuretted hydrogen, under suitable conditions.[1]

16. The curious highly refracting granules noticed so often already in the red-coloured organisms are similar to those which have been observed in *Beggiatoa;* they are, as Cohn shows, particles of sulphur.

By heating Beggiatoa-fibres on a slide the granules are caused to melt and form a large yellow drop, which gives off the smell of sulphurous acid; this experiment leaves no doubt as to their being sulphur; with polarised light they are doubly refractive, but their small size and high refractive index make it impossible for us to see their crystalline form. Similar experiments have succeeded with *Clathrocystis, Monas,* and *Ophidomonas.*

The question asked just above is now fully answered in favour of the living organisms.

17. The suggestion that *Bacterio-purpurin* is due to the formation of sulphur commends itself to Cohn, although he is unable to prove the truth of it, as yet. Mr. Lankester has pointed out that this colouring matter differs from that found by Schröter in *Micrococcus prodigiosus,* and Cohn points out that both differ, in the absence of chlorophyll, from the colouring matter of *Palmella cruenta* and other plants, such as the *Phycochromaceæ.*

18. Blood-coloured milk was observed to owe its appearance to the colouring matter of *M. prodigiosus,* which Cohn, by the way, finds to be soluble in alcohol and ether, unlike Bacterio-purpurin, as well as in the fat-globules (Buttertropfchen) of milk. An interesting use of the microspectroscope is also noted; Cohn recognised the colouring matter of *M. prodigiosus* in a capillary vessel containing the red milk, where he was unable to recognise by the microscope the forms of the organism which produced it.

19. Our author remains true to his original position, that the Bacteria may be arranged in two series; one containing *Micrococcus* and *Bacterium,* which run parallel to the *Chroococcaceæ,* and pass through a resting or *zooglœa* stage, while the other contains *Bacillus, Vibrio,* and *Spirillum,* which run parallel to the *Oscillariæ,* and pass through the *Leptothrix,* as their resting stage; and this, although many of the *Oscillariæ* become surrounded by gelatinous membrane, that is, take on the appearance of zooglæa; and while Professor Lan-

[1] The Euglenæ also exist and increase in such waters.

kester went a long way towards convincing him that *Spirillum undula* formed zoogloea masses (cf. 'Quar. Jour. Micro. Sci.,' xiii, Plate XXII, figs. 8 and 9), Cohn himself saw a colourless Leptothrix-like fibre in a "glia"; but as he never observed genetic connection between this form and *Spirillum,* he thinks it better to call it *Myconostoc* n. g., as it is among the Bacteria, a form parallel to Nostoc among the Algæ, and to give it the specific name of *gregarium,* because of its social character.

20. Another new genus (*Cladothrix dichotoma*), which Cohn has lately observed, gave him, at first, a great deal of trouble; he found colourless fibres very finely granulated, and apparently unsegmented, which resembled *Leptothrix,* save in this that they appeared to branch with great regularity; this was difficult to believe, because neither *Leptothrix* nor *Oscillariæ* ever present such branchings; but examined with a higher power, these organisms were seen not to present a true dichotomy, but that false branching which is so characteristic of the *Scytonemeæ* allied to the Oscillariæ, which is brought about by the apposition of two fibres, which, while growing divergently at their upper, grow in apposition at their lower ends.

This mode of origin of false branches agrees so closely with that observed in *Schizosiphon* and other *Oscillariæ,* that Cohn congratulates himself on the discovery, as tending to confirm his views of the close relationship which these putrefactive forms have to the *Oscillariæ.*

21. The next Bacterium described is also a new species, although the genus *Streptothrix*—the new form has the specific name *Foersteri*—is well known; the place in which this form was found was the lachrymal canal, where such organisms were first observed, in 1855, by the famous von Graefe, since which time other observers have also noticed them. Professor Foerster coming across it sent specimens to Cohn, who ree cognised specific differences between this form and th- *L. buccalis* which is found in the mouth, inasmuch as this latter is thicker, straight, while *L. Foersteri* is screw-shaped, like *Spirochæte.* *L. buccalis* is never branched as the new form frequently is. The full account of this form and the elaborate comparison which he sets forth between it and *L. buccalis* will have much interest for those who busy themselves with these remarkable parasites.

22. It would be strange, indeed, if any writer on Bacteria in the sad times in which our lot is cast, should not have his say about the question of spontaneous generation, flooded although we have been with literature on the subject. Cohn's

discussion on "lasting spores" (Dauersporen) is really of interest. He has already referred to the subject in his previous essay; there noting the great probability of *Bacillus* being reproduced by gonidia or lasting spores, which had an oily highly refractive internal substance; three observers, Perty, who called them *Hygrocrocis,* Trécul, who described them as *Urobacter,* and Billroth, who gave them the name of *Helobacteria,* had already observed these spores. Cohn having carefully repeated Bastian's experiments,[1] found that after three or four days the fluid was troubled, not by *B. termo,* but by *Bacillus.* Wondering, therefore, whether there were not certain forms of these organisms which could withstand the effects of boiling, he applied himself to what we will call the natural history of cheese.

23. Having observed the whole process, he thinks the operation consists of three parts:

(1.) The coagulation of the milk, which, as he says, is due not to organised, but merely to non-organised ferments (chymosin), comparable in action to diastase and pepsin.

(2.) The separation of the coagulated casein from the whey, which is a purely mechanical process, comparable to the separation of butter from milk, or fibrin from blood.

(3.) The coming to maturity of the cheese, which is a true fermentation, caused by ferment organisms (Zymophytes), accompanied by the evolution of gases and the formation of spaces, as in bread; the heat which is applied (55—60°) kills *B. termo,* and appears to leave free play for the activity of the peculiar ferment organisms of the cheese.

24. The Bacilli, represented in figs. 6—8, were more closely studied in the laboratory at Breslau; they were obtained from the rennet of a calf, of five to seven weeks old. It was found that their activity was lessened at 50° C., but below 30° was destroyed; they were seen to be actively moving, long, fine Bacilli, ordinarily paired, but sometimes united by fours or eights, never absent from the extract of the rennet. They are probably found in the living stomach, and such forms have, indeed, been already observed by Remak (1845) and Wedl (1858); they also appear to be the same as Pasteur's *B. subtilis,* which are so remarkable for their resistance to high temperatures, as well as for their activity in air deprived of its oxygen. If the fluid in which these are found be kept for some time at 30°, there are to be observed fibres with a swollen extremity, filled with oval slightly refractive granules, which, closely resemble in form the

[1] 'Proc. Royal Soc.,' 1873, No. 145.

spermatozoa of vertebrates, and rapidly increase in number; these are clearly either Heterocysts, or, as is more probable, *spores*, which belong to the life-history of *Bacillus*, and are produced under certain conditions. If this be so, Bastian's experiments are explained, for the spores were able to resist the comparatively short boiling to which they were subjected, and easily grew to maturity in the nutritive fluid in which they found themselves. In many other cases Cohn says he has observed such lasting spores; and lest some one, tempted by peas instead of cheese, should feel inclined to write two volumes on the 'Beginnings of Life,' it had better at once be added, that a similar putrefaction was observed in a solution of peas in *distilled water, which had been kept for several days at* 45° C.

25. *Spirochæte Obermieri* is already known to English pathologists from Dr. Burdon Sanderson's Report on the Pathology of Infective Processes,[1] where he figures, from a drawing sent by Cohn, the "spirillum" of relapsing fever. So full an account is there given, that it will be here sufficient to add what Cohn has since discovered concerning these organisms. They do not belong to *Spirillum*, but to the genus *Spirochæte*, of which only one species, *S. plicatilis*, has been hitherto known; and that, thanks to the labours of Ehrenberg, who, like Cohn, found it in the water of marshes. This latter differs from *Spirillum* in the character of its movements, which are at times serpentine; the screw-like windings of the fibres are constant in character, but their length is most variable. In addition to the serpentine movements, by which they are enabled to change their place, they also exhibit an undulation passing along their whole length, which has never been observed in *Spirillum*. Cohn is unable to say whether the form found in the blood is the same as that which is found in marshy water; if so, it is quite possible that the fever was produced by drinking it; another Spirochæte, however, was once observed by Cohn in the mucus of his own mouth, which appears to be intermediate between these other two forms.

It may be added that osmic acid, as Weigert has shown, preserves their characters unchanged.

26. The bacterium of splenic fever was also cited by Dr. Burdon Sanderson;[2] Cohn now gives it the name of *Bacillus Anthracis*, which differs from the *Bacillus* of butyric fermentation (*B. subtilis*), in being shorter and firmer, and

[1] Report of Medical Officer of the Privy Council, &c., N. S., No. III, 1874, p. 41.

[2] *loc. cit.*, p. 35.

never exhibiting movement; he cannot agree with Bollinger in thinking that the rods are formed by rosary-chains, and says that he has only found the refractive spheroids in dead specimens; while the question of their relation to Micrococcus must still remain undecided. Further, this form appears to agree with other *Bacilli*, in the possession of lasting spores, by which probably the contagium is spread. Brauell has shown that the placenta forms a true filter, and that the blood of the fœtus may be free from *Bacilli*, while that of the mother is full of them; and as the fœtus does not suffer from splenic fever, Bollinger is justified in asserting that the organisms themselves, and not the blood, are the cause of offence.

27. Cohn just refers to the Bacterium of the diseased silkworm, which he has called *Micrococcus bombycis*, oval bodies, something like *M. ureæ*, arranged either singly or in chains of varying length; he hopes to go into their history in the next issue of his 'Beiträge.'

28. In conclusion, there are a few remarks on the natural relationships of the genera of Bacteria, with a classification, which is appended in full; the position which Cohn has taken up, and which is now generally accepted—that is, that the Bacteria are plants, more closely allied to the Algæ than to the Fungi—is again supported by our knowledge of the forms just described; consequently neither Naëgeli's name *Schizomycetes*, nor Cohn's *Schizosporeæ*, are very good; perhaps *Schizophytæ* is the most suitable name for this first and simplest division of living beings, even if its characters are more negative than positive. The cells of the *Schizophytæ* are either free, or united into cell-families; in the latter case they are arranged either in one plane or on the surface of a sphere, or as cellular bodies; the groups thus produced may be formless, or surrounded by a definite and common envelope; the cell-series may be simple, or exhibit spurious branchings, and these series may be single or united into bundles. They increase by binary cell-division, and the divided cells may be all in one plane, or arranged as a cross, or in all three directions. Sexual reproduction is unknown; lasting spores have been frequently observed; spontaneous movements have been seen, at least for a short time; they cannot be separated, save for convenience, according to their colours and size; the cells are various in size and shape.

SCHIZOPHYTÆ.

TRIBE I.—*Glœogenæ.*

Cells free, or united by intercellular substance into cell-families.

A.—Cells free, or united in twos or fours :
Cells rounded . . . . *Chroococcus*, Naeg.
Cells cylindrical. . . . . . . *Synechococcus*, Naeg.

B.—Cells united into an amorphous gelatinous family in their resting stage.

a.—The cell-membranes confluent with the intercellular substance.
I.—Cells very small, and without phycochrom :
Cells rounded . . . . *Micrococcus*, Hall. emend.
Cells cylindrical. . . . . . . *Bacterium*, Duj.
II.—Cells larger, with phycochrom :
Cells rounded . . . . *Aphanocapsa*, Naeg.
Cells cylindrical. . . . . . . *Aphanothece*, Naeg.

β.—Intercellular substance formed by the cell-membranes running into one another.
Cells rounded . . . . *Glœocapsa*, Kg. Naeg.
Cells cylindrical. . . . . . . *Glœothece*, Naeg.

C.—Cells united into a gelatinous family, of well-defined form.
a.—Cell-families in one layer :
I.—Cells arranged in fours, in one plane, *Merismopedia*, Meyen.
II.—Cells in no order, arranged on the surface of a sphere.
Cells rounded ; the families form nets by fission . . . . . } *Clathrocystis*, Henfr.
Cells cylindrical and wedge-shaped; the families divide by the appearance of furrows } *Cœlosphærium*, Naeg.

β.—Cell-families in several layers, united into spheroidal cell-bodies :
I.—Cells definite in number.
Cells rounded ; colourless ; in fours . . . . } *Sarcina*, Goods.
Cells cylindrical and wedge-shaped, in no order, with phycochrom . . . . . . } *Gomphosphæria*, Kg.
II.—Cells indefinite in number, but that very large.
Cells colourless, very small . . *Ascococcus*, Billr. emend.
Cells larger, with phycochrom . { *Polycystis*, Kg. *Coccochloris*, Spr. *Polycoccus*, Kg. et al.

TRIBE II.—*Nematogenæ Rab.*

Cells arranged in rows.

a.—Cell-threads free, or in a felted mass:

I.—Threads cylindrical, colourless, indistinctly jointed.

Very fine and short	*Bacillus*, Cohn.
Very fine and long	*Leptothrix*, Kg. em.
Thicker and long	*Beggiatoa*, Trev.

II.—Thread cylindrical, containing phycochrom, distinctly jointed:

Reproductive-cells unknown .	*Hypheothrix*, Kg. *Oscillaria*, Bosc. et al.

III.—Threads cylindrical, jointed, forming Gonidia:

Colourless	*Crenothrix*, Cohn.
With phycochrom	*Chamaesiphon*, et al.

IV.—Threads screw-shaped:

1. Without Phycochrom.

Short, slightly undulating . .	*Vibrio*, Ehr. em.
Short, spiral, stiff	*Spirillum*, Ehr.
Long, spiral, flexible	*Spirochæte*, Ehr.

2. With Phycochrom.

Long, spiral, flexible	*Spirulina*, Link.

V.—Threads form a rosary-chain:

Without phycochrom	*Streptococcus*, Billr.
With phycochrom	*Anabæna*, Borg. *Spermosira*, Kg. et al.

VI.—Threads whip-like, growing at the point	*Mastigothrix*, et al.

β.—Threads united into gelatinous families by their intercellular substance:

I.—Cylindrical and colourless . . .	*Myconostoc*, Cohn.
II.—Cylindrical, with phycochrom	*Chthonoblastus.* *Limnochlide*, Kg. et al.
III.—Forming rosary-chains . . .	*Nostoc-Hormosiphon*, et al.
IV.—Whip-like, growing at their point	*Rivularia*, Roth. *Zonotrichia*, Kg. et al.

γ.—Threads exhibit spurious branching:

I.—Cylindrical and colourless . .	*Cladothrix*, Cohn. *Streptothrix ?*
II.—Cylindrical, with phycochrom	*Calothrix*, Kg. *Scytonema*, Kg. et al.
III.—Forming rosary-chains . .	*Merizomyria*, Kg. *Mastigocladus*, Cohn.
IV.—Whip-like, growing at their point	*Schizosiphon*, Kg. *Geocyclus*, Kg. et al

In the paper which concludes this 3rd Heft, Dr. Edward Eidam, who has been working under Cohn's direction in the University of Breslau, takes up the interesting questions of the influence of different temperatures, and of drying on *Bacterium termo*, Duj., with special regard to its development. Cohn himself had worked at the subject, and in his previous paper (in Heft II) had found the maximum mortal temperature (the experiment lasting for an hour) to be about 60° to 62° C. But both Cohn's points and that of Schröter

(59° C.) apply only to Bacteria *in a clear watery fluid.* On the other hand, Horwarth has studied the minimum mortal temperature, and finds that Bacteria can survive after having been exposed to a temperature of —18° C.; at such a point, indeed, they pass into cold rigor, but at a higher temperature again become vitally active. The breeding and feeding solution used was that which Cohn has already described; but, as in the previous account in this Journal, the proportions of the constituents were not given, it may be well now to add them:

Potassium phosphate . . .	1·0
Magnesium Sulphate . . .	1·0
Ammonium Tartrate . . .	2·0
Calcium Chloride . . .	0·1
Distilled Water . . .	200·0

If kept at 50° C., this solution will remain quite free from Bacteria.

From eighteen experiments carried out for the purpose of seeing the effects of different temperatures, Eidam concludes that at 5° C. there is no reproduction (here it should be remarked, that a similar tube to those which produced this result was placed in a warm chamber at 30° to 35° C., and that Bacteria were actively reproduced in it); but at 5½° C. reproduction began, though very slowly, and so on up to 10° C.; above which point reproduction began to be much more energetic, and so continued up to 30° to 35° C.; above 35° C. it fell, at 40° the Bacteria fell into heat-rigor, and died at 60°.

From these experiments also could be drawn a confirmation of what Cohn in his first paper so wisely remarked, "Putrefaction is a correlate phænomenon, not of death, but of life;"[1] for in those tubes, to which the drop containing Bacteria was added, without an increase of these organisms becoming apparent—that is, in those kept at very low temperatures—there was no putrefaction, but as the temperature was raised, and the Bacteria began to multiply, this concomitant of Bacterian vitality began to show itself, and with these conditions the intensity of the smell of putrefaction went hand in hand.

But there was a smell, as of cheese, in some tubes kept at 44° to 46°, to which albumen or peas had been added; whence came this so sure, even if so disagreeable sign of vitality, if it be true that at such temperatures *Bacterium termo* is in a state of heat-rigor? Microscopical examination revealed the presence of Bacillus-filaments and lasting spores;

[1] Heft II, p. 204.

and such observation was sufficient to satisfy the author, that butyric fermentation was taking place.

The experiments on the influence of the length of the time of heating on Bacteria showed that—

(α) Heating for twenty-five hours at 40° was not sufficient to kill them; but the delay in commencing to increase in number which was observed when they were placed in the warm-chamber, showed that they had suffered from heat-rigor.

(β) Thirteen to fourteen hours' heating at a mean temperature of 46°, or

(γ) Three hours at 51° was sufficient to kill them.

But if *Bacterium termo* be exposed to a temperature of 50° C. in the *dry*, it still retains its vital activity even if the experiment be continued for as much as six hours, (lower temperatures such as 15° to 16° continued for a week did not destroy the Bacteria); such an experiment would tend to show that the surrounding membrane must be of considerable value, as a protector to the protoplasm within.

Finally, glass rods that had been dipped in a fluid containing Bacteria, and then dried for an hour at 15° C. were brought for a moment in contact with ammonia, alcohol, crude carbolic acid, and acetic acid; and again dried for an hour in the air; the only liquid that proved fatal was the last.

Eidam concludes by insisting on a careful and continuous study of the varying conditions of life, which obtain among the Bacteria.

EXPLANATION OF PLATE XX,

Illustrating Mr. Jeffrey Bell's Account of Recent Researches into the History of Bacteria, made by and under the direction of Professor Cohn.

Fig. 1.—*Ascococcus Billrothii*, large knob-like cell-families, surrounded by smaller ones, and embedded in *Micrococoocus*.

Fig. 2.—*Myconostoc gregarium:* Gelatinous spheroids, in which are fibres irregularly placed and rolled together. *a*, *b*. Single spheroids. *c*. Division of a spheroid, commencing by the separation of the fibres. *d*. a large coil of fibres in the very act of division. *e*. Fibres separated from one another by the breaking up of the gelatinous envelope. *f*. Fibres in ring-shaped pieces. × 600.

Fig. 3.—*Streptothrix Foersteri;* branched, and screw-form fibres from a tallowy mass, taken from the lachrymal canal of a human subject. *a*. Fibres with which are embedded *Micrococci;* the rest were isolated by the separation of the Micrococci. *b*. A thicker mycelium-like fibre. × 600.

Fig. 4.—*Cladothrix dichotoma.* Dichotomous fibres forming white mucous masses on the surface of putrefying fluids. × 600. *a*. The false dichotomy is clear. × 600.

Fig. 5.—*Bacillus anthracis:* Bacilli from the blood of a cow that had died of splenic fever, examined after death. × 600.

Fig. 6.—*Bacillus subtilis. a.* Bacterian fibres from an extract of rennet, in lively movement; *b*, with spores; *d*, spores with short fibres (? budding spores).

Fig. 7.—*B. subtilis.* Bacterian fibres from a solution of boiled peas in which butyric fermentation had begun; the spores in a row. × 600.

Fig. 8.—*Micrococci* with embedded Bacillus-spores. *

Fig. 9.—*Micrococcus Bombycis:* from the gastric fluid of a living silkworm, affected with the disease (flaccidezza); oval cells arranged in rows, either in pairs or in chains of varying length.

Fig. 10.—*Clathrocytis roseo-persicina:* a net-like cell family.

Fig. 11.—*Monas Warmingii:* motile Monads with flagellum: in * the division is just beginning, in ** it has gone farther. × 600.

Fig. 12.—*Monas Okenii:* actively motile monads; and division beginning. × 600.

FIG. 13.—*Monas vinosa :* Monads in lively movement and in division; the flagella were not clearly seen. × 600.

FIG. 14.—*Rhabdomonas rosea ;* slowly moving monads; * in the act of division. × 600.

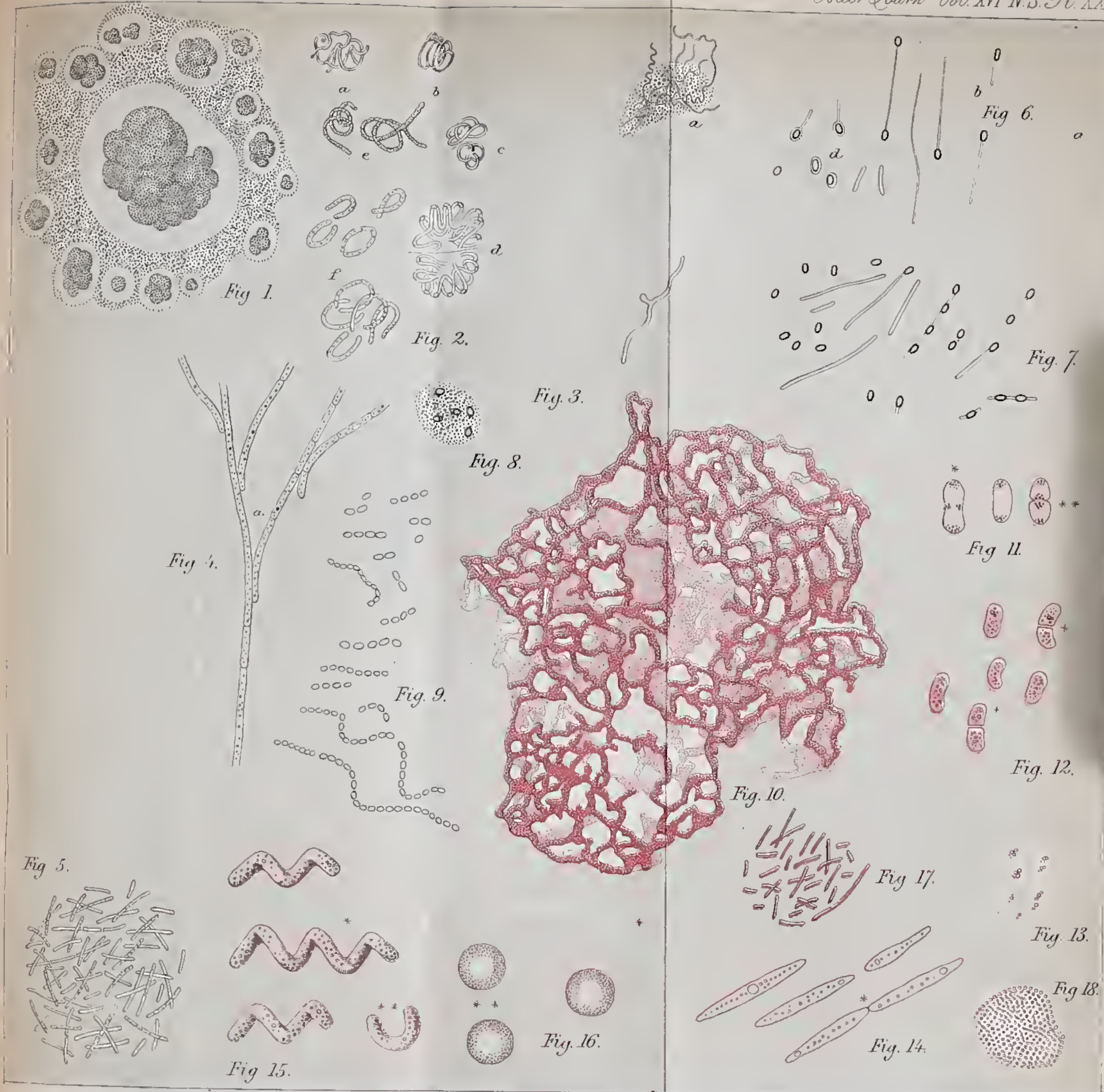
FIG. 15.—*Ophidomonas* (*Spirillum*) *sanguinea ;* Monads with flagellum at one, at both (*) ends: ** semilunar form. × 600.

FIG. 16.—*Spirochæte Obermeieri ;* screw-fibres, actively moving among blood-corpuscles (**); * shortly before the cessation of the fever. × 600.

FIG. 17.—*Bacillus ruber*: rods, forming red spots on rice.

FIG. 18.—*Micrococcus fulvus :* colonies, forming rust-red drops of mucus on horse-dung.

All the figures were drawn with Hartnack's objectives. Figs. 10 by Dr. Kirchner, 16 by Dr. Weigert, and the rest by Cohn.



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